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CONTROL of Runoff and Erosion

on Almena Silt Loam in Wisconsin

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CONTROL OF RUNOFF AND EROSION ON ALMENA SILT LOAM IN WISCONSIN

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The conservation problems encountered on a gently sloping, poorly drained soil in North Central Wisconsin were considered to be sufficiently different from those found on sloping, moderately well drained soils to require special study. The soil studied is the Almena silt loam, found in the Spencer silt loam area where inadequate drainage and excessive erosion frequently occur on the same field. Internal drainage is limited by a silt pan which also limits root penetration and permeability. Nelson and Muckenhirn(2)[2] found that on Spencer silt loam the infiltration rate of the plow layer was 0.54" per hour, of the B_1 horizon, 0.046" per hour, and of the B_2 horizon, zero inches per hour. The Almena is considered by soil scientists to be less permeable than the Spencer of this data.

In an attempt to improve surface drainage, farmers in this area have been practicing a bedding system consisting of frequent dead and back furrows extending up and down slope. This practice concentrates runoff water and seriously increases erosion on typical farm slopes. Slope lengths of 800 to 1,000 feet are common with steepness varying from 1 to 4 percent. Although farmers recognize that erosion is a serious problem, they have hesitated to adopt the conservation practices generally recommended by the Soil Conservation Service for fear that crops planted on the contour would produce lower yields.

[1] Soil Conservationist, Soil & Water Conservation Research Division, Agricultural Research Service, USDA, and Chairman, Department of Soils, University of Wisconsin, respectively. Credit is due George W. Wunnecke, Agricultural Aid.

[2] Numbers in parentheses refer to Literature Cited, at the end of report.

Design of experiment

In 1944, the Wisconsin College of Agriculture in cooperation with the Clark County Board of Supervisors, the Soil Conservation Service, and the Wisconsin State Soil Conservation Committee, established an experiment on the Clark County Hospital Farm near Owen to determine the effects of terraces and row direction on crop yields and the ability of these practices to reduce runoff and erosion. The field selected for the runoff studies from plots and terraces has a slope of approximately 3 percent and a slope length of about 800 feet. The plots were 100 feet wide by 300 feet long. Terraces about 400 feet long were constructed at a vertical interval of two feet with a channel grade of six inches per one hundred feet. Figure 1 shows the plot and terrace layout.

The treatments were a 4-year rotation of corn, spring grain, and two years of hay - planted on the contour, planted up and down slope, and planted parallel to the terraces - and a 3-year rotation of fall grain (changed to spring grain in 1953) and two years of hay - planted up and down slope and planted on the contour.

All areas received an initial application of 750 pounds of 0-20-20 fertilizer and 4 tons of finely ground limestone per acre. Maintenance treatments included 10 tons of barnyard manure and 150 pounds of 3-12-12 per acre on corn and 400 pounds of 0-9-27 per acre on grain in the corn, grain, hay, hay rotation. In the grain, hay, hay rotation, the grain received an application of 7.5 tons of barnyard manure, 300 pounds of 0-9-27, and 112 pounds of 3-12-12 per acre. On an annual basis, the per-acre rates of application are the same for both rotations and were considered adequate for optimum yields on this soil.

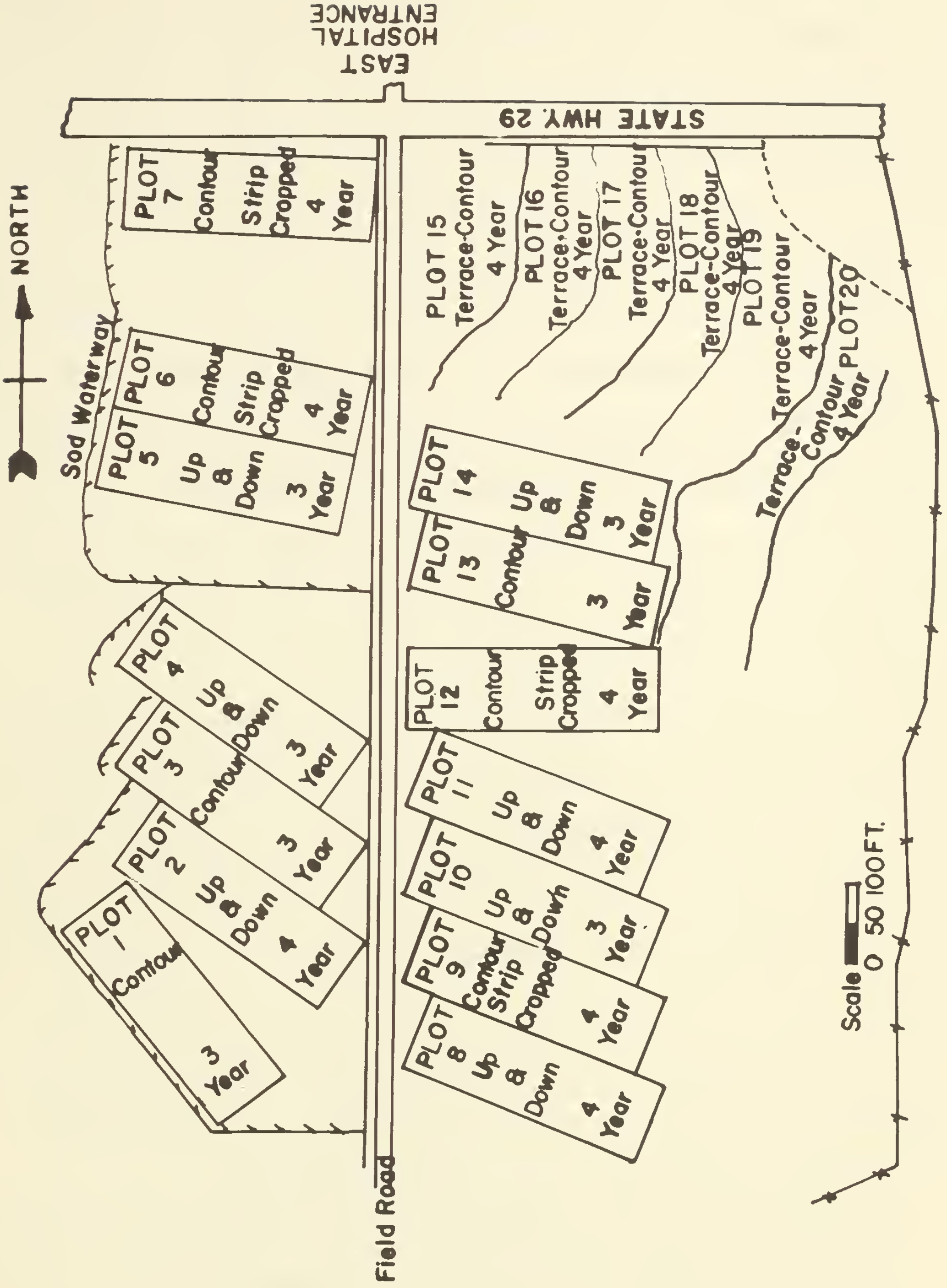

EAST HOSPITAL ENTRANCE
STATE HWY. 29
NORTH
Sod Waterway
Field Road
PLOT 1 Contour 3 Year
PLOT 2 Up & Down 4 Year
PLOT 3 Contour 3 Year
PLOT 4 Up & Down 3 Year
PLOT 5 Up & Down 3 Year
PLOT 6 Contour Strip Cropped 4 Year
PLOT 7 Contour Strip Cropped 4 Year
PLOT 8 Up & Down 4 Year
PLOT 9 Contour Strip Cropped 4 Year
PLOT 10 Up & Down 3 Year
PLOT 11 Up & Down 4 Year
PLOT 12 Contour Strip Cropped 4 Year
PLOT 13 Contour 3 Year
PLOT 14 Up & Down 3 Year
PLOT 15 Terrace-Contour 4 Year
PLOT 16 Terrace-Contour 4 Year
PLOT 17 Terrace-Contour 4 Year
PLOT 18 Terrace-Contour 4 Year
PLOT 19 Terrace-Contour 4 Year
PLOT 20 Terrace-Contour 4 Year
Scale 0 50 100 FT.

Figure 1. Surface Runoff & Erosion Control Experimental Plots
Clark County Hospital Farm, Owen, Wisconsin

Cooperating Agencies: Clark County, University of Wisconsin College of Agriculture, United States Soil Conservation Service

In 1947 and 1948 the Research Division of the Soil Conservation Service installed runoff-measuring equipment on plots 33 feet wide by 300 feet long within the larger plots and also at the outlet end of the terraces. All treatments were placed under measurement except the 3-year rotation planted on the contour. The runoff-measuring equipment consisted of a one-foot H-type flume with water-stage recorder to determine rates and amount of runoff and a Coshocton inclined wheel (developed by W. H. Pomerene of the North Appalachian Experimental Watershed, Coshocton, Ohio) to obtain an aliquot of the runoff suspension. Runoff measurements, except for a few plots, were limited to the ice-free portion of the year. On the plots measured during the winter, heated shelters were used to prevent ice from forming in the flumes and on the wheels until it was determined that soil loss was very low during the winter period.

In 1947 the treatment of the 4-year rotation, contour-planted plots, was changed to contour strip cropping with the same rotation. The two-crop system was followed, with two plots in corn and hay and two plots in grain and hay. Crop sequence was arranged so that each crop was represented on the bottom strip each year.

Rainfall

Crop-yield data were obtained, beginning in 1945. Rain-gage records began in 1947 and runoff and soil-loss measurements in 1947 and 1948. The experiment was terminated on November 15, 1955.

Average annual precipitation for the 9-year period was 27.7 inches. The extremes were 21.4 and 33.4 inches. The 40-year average of four nearby Stations was 32.8 inches. The period sampled, then had lower average annual rainfall than might be expected for this area.

Rainfall intensities were compared with Yarnell's rainfall intensity-frequency data (4). There were five rains with 30-minute intensities equal to or in excess of the 2-year expected intensity for this area. One rain had an intensity nearly equal to the 5-year frequency. The intensity data, thus, were close to the expected for a 9-year period.

The time of year during which intense rains occur is known to be an important factor influencing runoff and soil loss. Three of the five intense rains occurred during the last half of June, one in August, and one in September. By June, grain and hay are giving good cover to the soil. Soil and water losses would be expected to be relatively low from these crops when well established.

Runoff

Amounts of runoff, in inches, are shown in Table 1 in full and in Figure 2 for the 4-year rotation with crops planted up and down slope. Corn land lost more runoff than grain land in seven of the nine years of measurement. Hay allowed about 40 percent as much runoff as corn. The eight years with runoff measurements on all areas were divided into years of high and low rainfall. The four high years (1949-50-51-54) had an average annual rainfall of 30.3 inches; the four low years (1948-52-53-55) had an average rainfall of 25.1 inches per year. During the years of low total precipitation, runoff from hay averaged 16 percent of that from corn land. During years of high precipitation, it averaged 54 percent as much as from corn.

Figure 3 shows the influence of conservation practices on runoff.

Contour strip cropping reduced the runoff from all crops as compared with up and down slope planting. The greatest reduction was on corn land. With corn on alternate strips, including the bottom strip, runoff was reduced by more than 50 percent, or from 2.07 inches to 0.95 inches per year. For all four crops, the average annual runoff from planting up and down slope was 1.36 inches. From planting in a strip crop system, it was only 0.69 inches. During the four years of high rainfall, runoff from strip cropping was 67 percent of that from up and down slope. During years of low rainfall, runoff from strip cropping was only 18 percent as much as from up and down slope planting.

Runoff from each crop planted on terraces was as much or more as that from the same crop planted up and down slope. Runoff for all crops averaged 1.36 inches for planting up and down slope, 1.58 inches for planting parallel to the terraces. Terraces were obviously more effective in the removal of excess rainfall than where terraces were not used and the crops were planted up and down the slope.

The surface soil layer was removed in the construction of the channels of the rather closely spaced terraces (82-foot horizontal, on an average land slope of 2.4 percent). Thus subsurface flow above the silt pan was intercepted by the channels with the result that runoff measured at the ends of the terraces included both surface and subsurface runoff. With the up and down hill and the contour strip crop plots, the measured runoff was practically all surface runoff. The 0.89 inches difference in average annual runoff between that measured for the strip crop plots and the terraces is a measure of the subsurface flow intercepted by the terrace channels.

Table 1: Effect of soil conservation practices on runoff

Crop on plot or bottom strip	Year	Runoff from cultivation			Annual Precipitation
		Up and down slope	Contour Strip Cropped	Terraced	
		- Inches -			
Corn	1947	2.57		1.12	26.8
	1948	0.60	0.05	0.01	21.4
	1949	2.19	2.17	2.51	29.0
	1950	2.75	0.48	2.23	27.9
	1951	2.13	2.38	2.94	33.4
	1952	1.99	0.36	1.43	24.9
	1953	1.81	0.64	2.93	27.4
	1954	2.69	1.48	3.14	30.9
	1955	2.42	0.05	1.06	26.7
Average	1948-1955	2.07	0.95	2.03	27.7
Oats	1947	1.69	-	1.64	
	1948	0.88	0	0.07	
	1949	3.57	0.96 ✓	2.85	
	1950	1.49	1.33	2.13	
	1951	1.63	1.52	2.62	
	1952	1.53	0	0.61	
	1953	1.02	0.17	0.71	
	1954	2.42	3.21	5.67	
	1955	1.73	0.21	1.85	
Average,	1948-1955	1.78	0.92	2.06	
Hay-1	1947	-	-	0.43	
	1948	0.09	0.07	0.01	
	1949	1.27	0.28	0.49	
	1950	0.27	0.54	0.49	
	1951	1.00	0.30	2.37	
	1952	0.56	0.25	1.44	
	1953	0.62	0.16	0.83	
	1954	2.20	1.70	2.45	
	1955	0.17	0.11	0.24	
Average,	1948-1955	0.77	0.43	1.04	
Hay-2	1947	-	-	0.09	
	1948	0	0	0	
	1949	1.06	0.94	0.76	
	1950	0.65	0.08	1.01	
	1951	1.88	1.56	2.50	
	1952	0.12	0.11	0.64	
	1953	0.49	0.33	1.45	
	1954	2.23	0.76	3.21	
	1955	0.17	0.01	0.10	
Average,	1948-1955	0.82	0.47	1.21	
Rotation average		1.36	0.69	1.58	

Figure 2: Effect of crop on runoff in a 4 year rotation cultivated and down slope

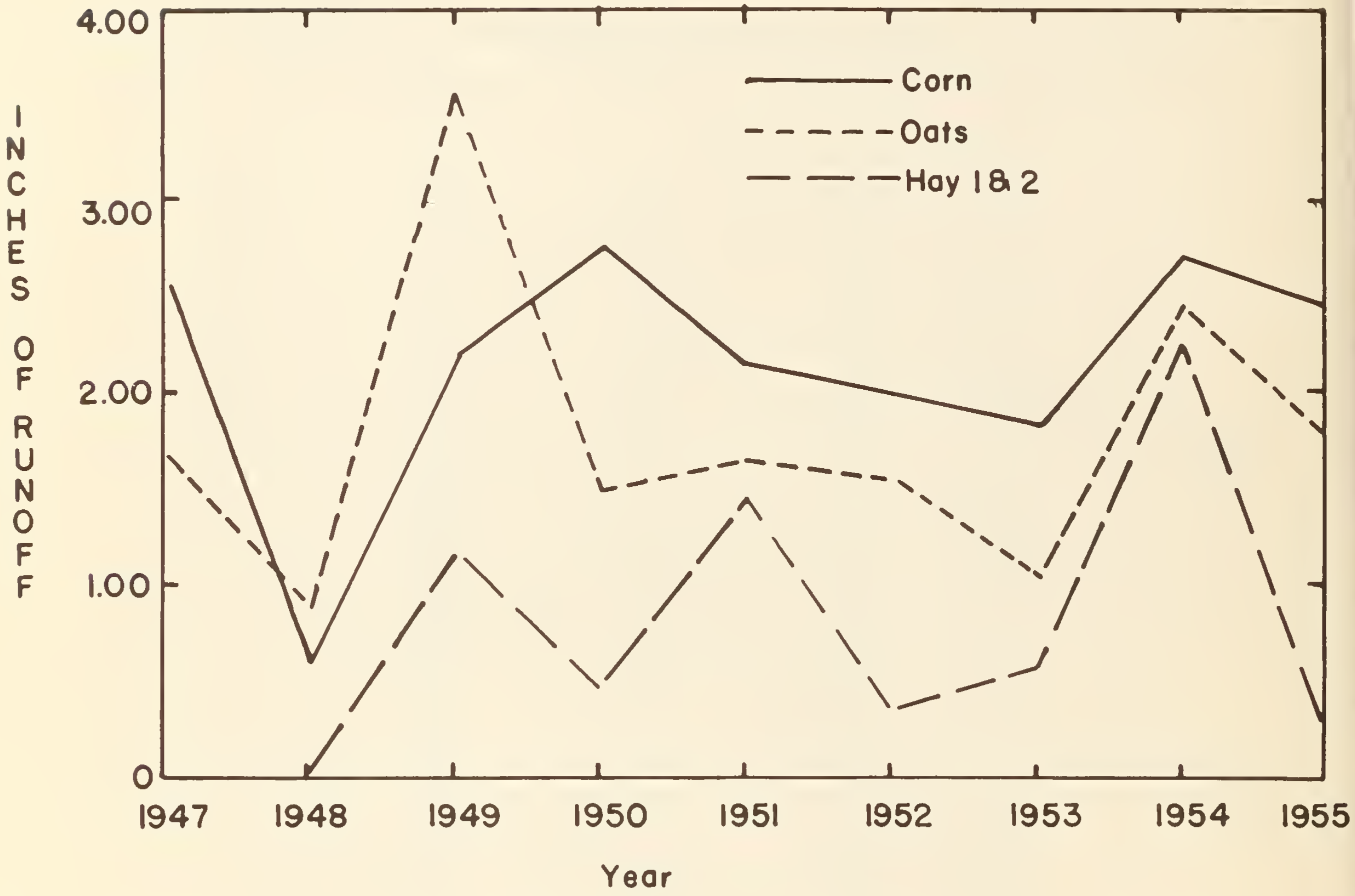
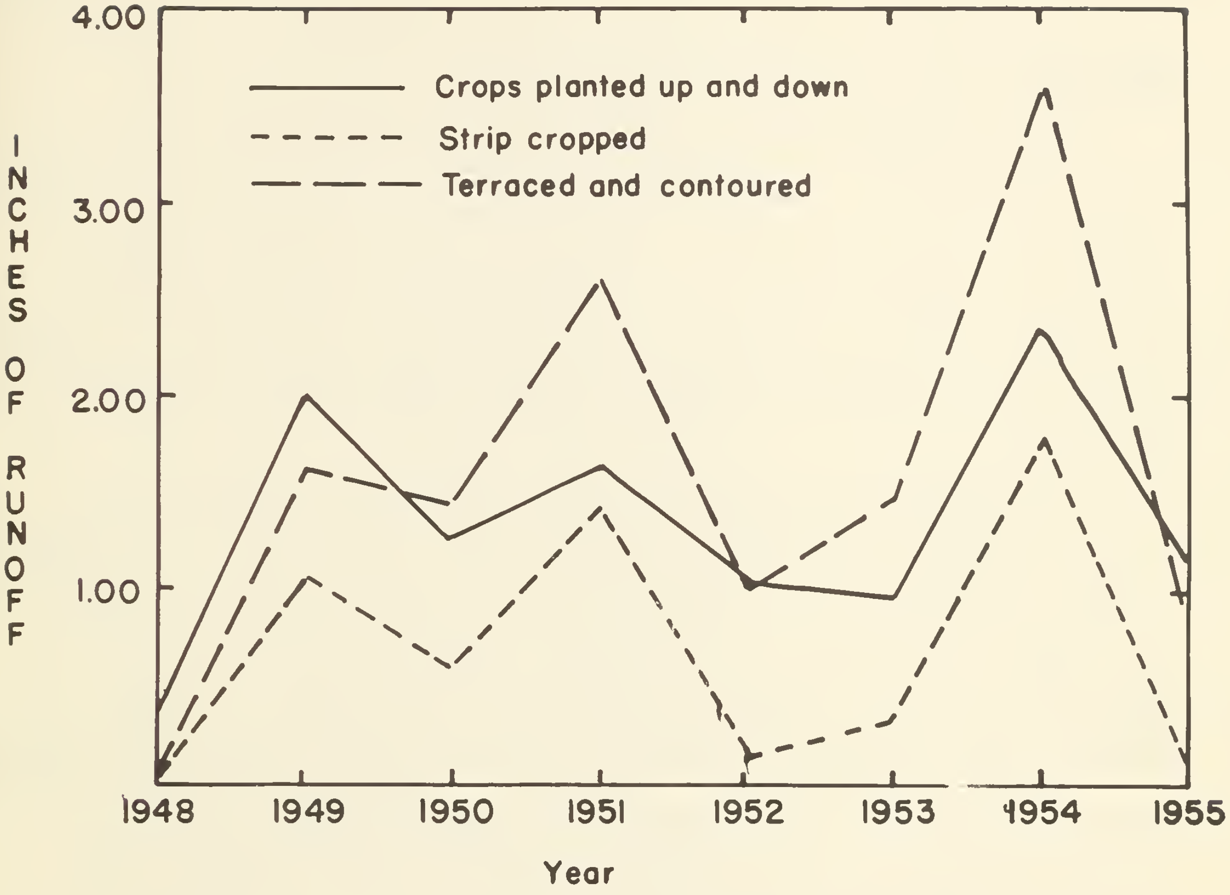


Figure 3: Effect of conservation practice on runoff (CGHH rotation)



Increasing the horizontal spacing of the terraces could be expected to decrease this difference and give less effective removal of the excess water.

Soil Losses

Soil-loss data are given in Table 2 and that of two grain crops in the four-year rotation are shown in Figure 4. The highest soil loss occurred on those areas where corn was planted up and down the slope. Under that system the average annual loss was 3.3 tons per acre. The highest soil loss measured in any year of the experiment was 8.9 tons per acre.

Slope length is an important factor influencing the amount of soil loss from a field. The slope length of the field on which this experiment was located is about 800 feet. The plots cropped up and down slope and the strip cropped plots were established with a slope length of 300 feet. Slope length data obtained at LaCrosse and other soil conservation experiment stations would indicate that the soil loss as influenced by slope length varies as the square root of the length in feet. Thus, applying this factor, the soil loss from the 800-foot length of slope would be expected to be 1.6 times the loss measured on the 300-foot plots.

During the 9-year period of measurement, there were 10 storms which resulted in a loss in excess of 1 ton per acre. Most of these rains occurred in June and July. Thirty-eight percent of the annual soil loss from corn land occurred in June and 35 percent in July, as shown in Table 3.

Figure 4: Effect of corn and oats on soil loss in four year rotation cultivated up and down slope

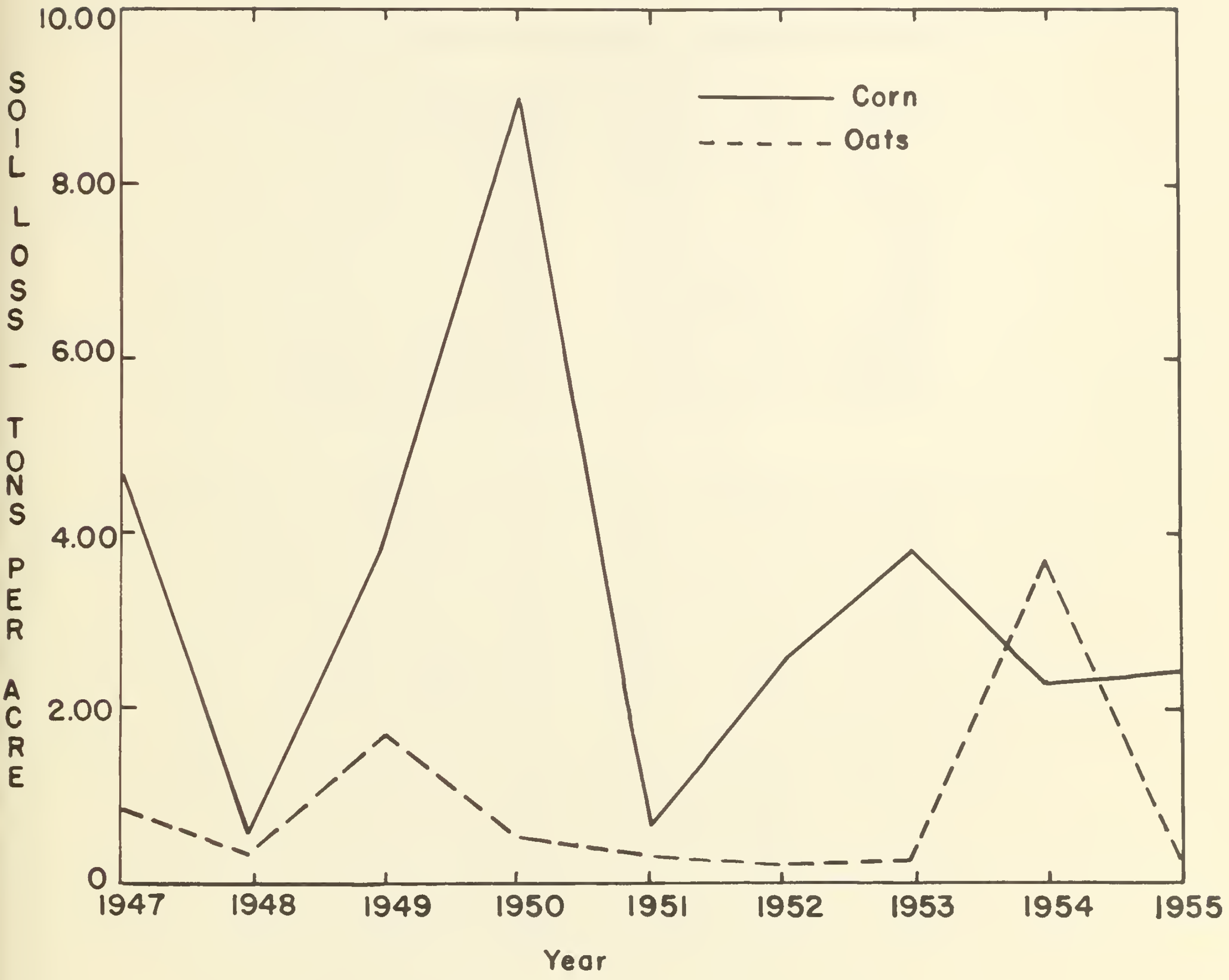


Table 3: Total soil loss by months, from corn planted up and down slope, 1947-1955

Month	Total 9-year soil loss,	Portion of total loss
	Tons/acre	Percent
March	0.08	0.3
April	1.91	6.0
May	0.13	0.4
June	11.92	37.7
July	11.09	35.1
August	2.92	9.2
September	3.13	9.9
October	0.44	1.4

Strip cropping very effectively reduced soil losses, as indicated in Figure 5. Even with corn and grain on the bottom strips, the soil loss was reduced to about one-fifth. Where corn was on the bottom strip the soil loss was reduced to about the same amount as when hay occupied the entire plot.

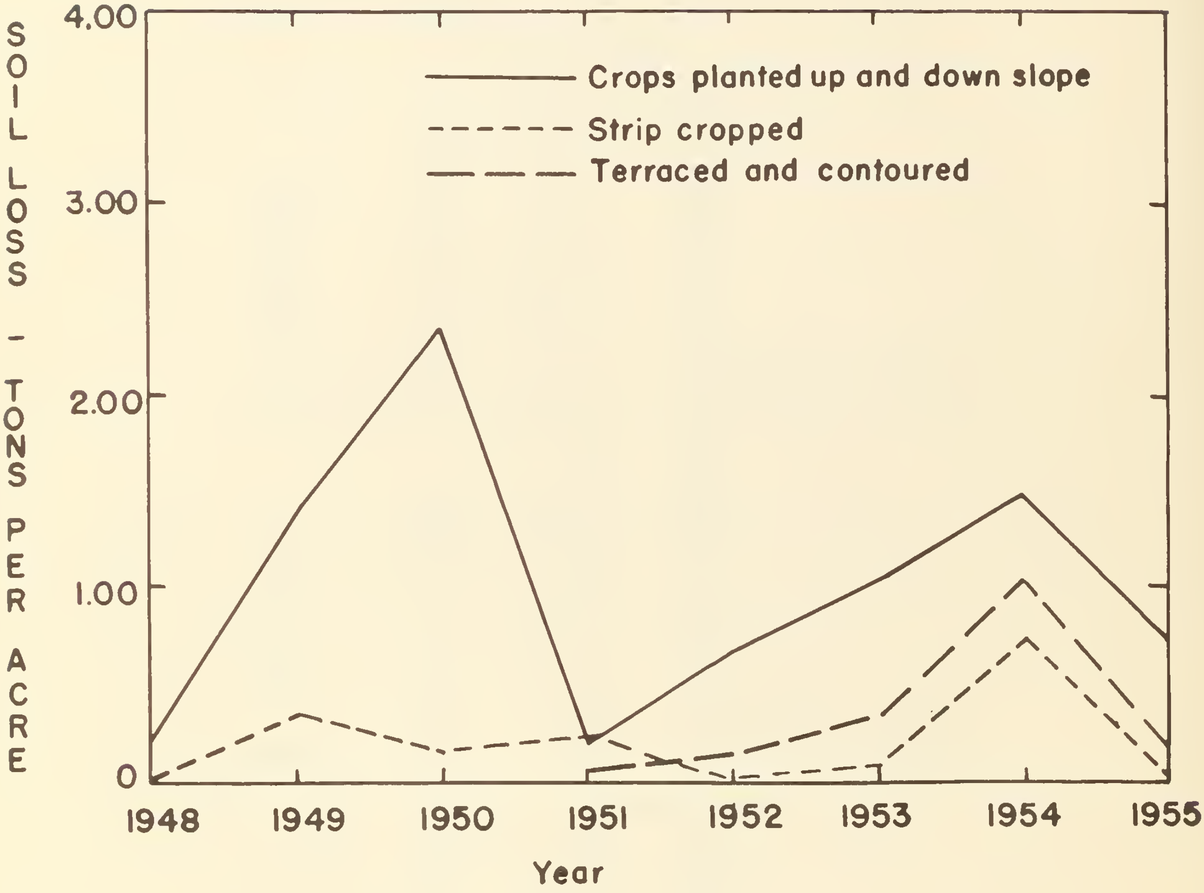
Coshocton wheels were not installed on the terraces until 1951. During the 5-year period for which soil-loss data are available, corn planted on the terraces lost about one-third as much as corn on the plots planted up and down slope but three times as much as strip cropping with corn on the bottom strip.

The average annual soil losses for the rotation from up-and down-slope planting, strip cropping, and terracing were 0.8, 0.2, and 0.4 tons per acre, respectively.

Table 2: Effect of soil conservation practice on soil loss

Crop on plot or bottom strip	Year	Up and down slope	Contour strip cropped	Terraced
		Tons/acre		
Corn	1947	4.66	-	-
	1948	0.56	0.02	-
	1949	3.87	1.16	-
	1950	8.88	0.60	-
	1951	0.65	0.64	0.20
	1952	2.50	0.05	0.55
	1953	3.86	0.33	1.30
	1954	2.26	0.22	1.08
	1955	2.39	0.04	0.51
Average,	1948-1955	3.12	0.38	-
Average,	1951-1955	2.33	0.26	0.73
Oats	1947	0.83	-	-
	1948	0.31	0	-
	1949	1.68	0.20	-
	1950	0.53	0.12	-
	1951	0.13	0.03	0.02
	1952	0.19	0	0.03
	1953	0.23	0.01	0.10
	1954	3.65	2.69	2.95
	1955	0.44	0.04	0.20
Average,	1948-1955	0.90	0.39	-
Average,	1951-1955	0.93	0.55	0.66
Hay-1	1947	-	-	-
	1948	0	0.02	-
	1949	0.03	0.04	-
	1950	0	0.05	-
	1951	0	0.16	0.02
	1952	0	0	0
	1953	0	0	0
	1954	0	0.01	0.02
	1955	0.03	0	0
Average,	1948-1955	0.01	0.04	-
Average,	1951-1955	0.01	0.03	0.01
Hay-2	1947	-	-	-
	1948	0	0	-
	1949	0.04	0.09	-
	1950	0.01	0	-
	1951	0.01	0.06	0
	1952	0.01	0	0
	1953	0	0	0
	1954	0.06	0.02	0.06
	1955	0	0	0
Average,	1948-1955	0.02	0.02	-
Average,	1951-1955	0.02	0.02	0.01
Rotation average				
	1948-1955	1.01	0.21	-
	1951-1955	0.82	0.22	0.35

Figure 5: Effect of conservation practice on soil loss in four year rotation



The data from up - and down-slope planting should not be used as a basis for assuming that it is not necessary to farm parallel to the terrace in this soil area. Wojta and Peterson (3), working on the Almena soil, have shown that plowing across the terrace at either a 45° or 90° angle to the terrace channel critically reduced the terrace capacity at the location of dead furrows and back furrows. Other farming operations did not seriously reduce channel capacity on these gentle slopes. Terraces were observed to reduce wet spots and markedly improve crop production at the lower end of long slopes.

Rotation

Two rotations, CGHH and GHH, with planting up and down slope, were under measurement. For the period 1944 to 1952, winter wheat, with legumes seeded on frozen ground, was grown in the 3-year rotation. The grain was changed to oats in 1953 because winter wheat frequently gave poor stands due to freezing. It also was difficult to obtain good stands of legumes in the winter wheat.

Table 4: Effect of rotation on soil and water losses from crops planted up and down slope

	Runoff Inches		Soil Loss Tons/acre	
Year	CGHH	GHH	CGHH	GHH
1948	0.39	0.11	0.22	0.06
1949	2.02	0.32	1.40	0.03
1950	1.29	0.78	2.36	0.02
1951	1.66	2.05	0.20	0.03
1952	1.05	0.22	0.68	0
1953	0.98	0.40	1.02	0.02
1954	2.38	1.94	1.49	0.81
1955	1.12	0.18	0.72	0
Average	1.36	0.75	1.01	0.12

Losses of both soil and water were quite low from both rotations. Average annual runoff from the CGHH rotation was 1.36 inches, from the GHH rotation 0.75 inches. The average annual soil loss from the CGHH rotation was 1.01 tons per acre, and from the GHH rotation 0.12 tons per acre.

Nutrient losses in runoff

Fertility erosion or the loss of plant nutrients is quite high from this soil. Runoff samples with soil suspension were taken from grain and corn plots after each runoff period and were analyzed under the direction of Dr. M. L. Jackson, Department of Soils, University of Wisconsin. Massey et al (1) found that a soil loss of 5 tons from oats and corn on the Almena soil contained 460 pounds of organic matter, 26 pounds of nitrogen, 0.81 pounds of available phosphorus, and 5.5 pounds of exchangeable potassium.

Crop yields

Corn yields were not greatly influenced by row direction or practice as shown in Table 5. For the 11-year period, land with corn planted up and down slope yielded 56.1 bushels per acre, contour strip cropped 56.3 and planted parallel to terraces 54.4 bushels per acre. Even though contour strip cropping reduced runoff by 0.67 inches, or 50 percent, yield of corn was not higher than when planted up and down slope. The yield data were divided into years of high and low rainfall in Table 6. There appears to be no great influence of row direction or practice on corn yields either in high or low rainfall years during the period of measurement.

Table 5: Effect of soil conservation practice on crop yields

Year	Crop	CGHH Rotation			GHH Rotation	
		Up and down slope	Contour strip cropped*	Terraced	Crop	Up and down slope
1945	Corn,	22.2	19.6	18.3		
1946	Bu./acre	37.1	42.7	37.1		
1947		53.2	53.9	56.8		
1948		82.2	68.4	80.3		
1949		83.4	79.8	84.0		
1950		36.8	36.7	35.0		
1951		32.3	38.8	41.2		
1952		89.3	102.0	89.8		
1953		68.2	62.7	52.7		
1954		63.0	59.9	52.2		
1955		49.2	54.4	51.1		
Average		56.1	56.3	54.4		
1945	Oats,	66.5	62.4	62.6		
1946	Bu./acre	60.7	67.3	71.5		
1947		51.8	33.4	44.3	W.wheat	24.6
1948		45.9	47.6	40.2		26.0
1949		38.7	23.6	36.2		21.0
1950		61.9	68.8	72.5		12.9
1951		72.7	79.3	86.3		17.6
1952		74.5	72.6	63.2		15.9
1953		59.5	53.1	50.8	Oats	55.7
1954		64.3	58.2	60.3		66.6
1955		56.7	65.8	52.1		59.6
Average		59.4	57.5	58.2		
1946	Hay-1,	3.8	4.1	3.9	Hay-1	3.8
1947	Tons/Acre	3.94	2.89	2.68		3.19
1948		2.90	2.38	2.33		3.04
1949		2.75	2.74	2.76		1.70
1950		4.22	4.52	4.64		4.07
1951		3.34	3.71	2.92		3.85
1952		3.21	3.02	2.72		2.57
1953		3.69	3.52	3.53		3.80
1954		2.67	3.26	2.66		3.56
1955		3.14	2.66	2.11		3.00
Average		3.37	3.28	3.02		3.26
1947	Hay-2	2.31	2.18	2.85	Hay-2	2.15
1948	Tons/Acre	3.38	3.34	2.86		1.86
1949		4.10	2.64	3.28		3.23
1950		4.26	4.64	4.55		2.99
1951		3.22	3.44	3.39		3.31
1952		3.27	3.01	2.79		2.73
1953		3.68	3.60	3.24		2.93
1954		2.57	2.72	2.22		2.16
1955		2.39	2.80	2.09		3.14
Average		3.24	3.15	3.03		2.72

* Contoured 1945 and 1946; contour strip cropped 1947-1955.

Yields of oats averaged 59.4 bushels per acre from up and down slope planting, 57.5 from contour strip cropping, and 58.2 from planting with the terraces. An examination of yields by years shows that terraces slightly increased the yield of grain during the high-rainfall years and slightly decreased yields during low-rainfall years.

Table 6: Effect of conservation practice and rainfall on crop yields

Rainfall	Up and down slope	Contour strip cropped	Terraced
	CORN - bushels per acre		
High	53.9	53.8	53.1
Low	72.2	71.9	68.5
	OATS - bushels per acre		
High	59.4	57.5	63.8
Low	59.2	59.8	51.6
	HAY - 1 - tons per acre		
High	3.24	3.56	3.24
Low	3.24	2.90	2.67
	HAY - 2 - tons per acre		
High	3.54	3.36	3.36
Low	3.18	3.19	2.74

Hay yields were, in general, slightly higher on the plots which were cropped up and down slope than on the other treatments, but during the high rainfall years hay production was as high on the contour strip cropped plots and the terraced areas as on the up and down slope plots.

Summary

Eight years of runoff, soil loss, and yield data are presented showing the influence of row direction, strip cropping, and terracing on a gently sloping, poorly drained soil.

Soil losses were not excessive, even for up and down slope planting. It must be recognized, however, that these plots were only 300 feet long, thus providing conditions similar to diversions spaced at 300-foot horizontal intervals, that the rotations under measurement permitted the land to be in hay at least 50 percent of the time, and that the fertility program was adequate to maintain good stands of alfalfa for at least two years.

The yield data did not indicate an advantage to planting up and down slope, nor was there a material increase or decrease in yield resulting from planting on the contour.

Crops planted parallel to the terraces allowed more runoff than the same crops planted up and down slope. With contour strip cropping, the reverse occurred.

The results indicate that contour strip cropping and terracing can be safely used on this poorly drained soil to reduce erosion and control runoff under a good soil management program without reducing crop yields.

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